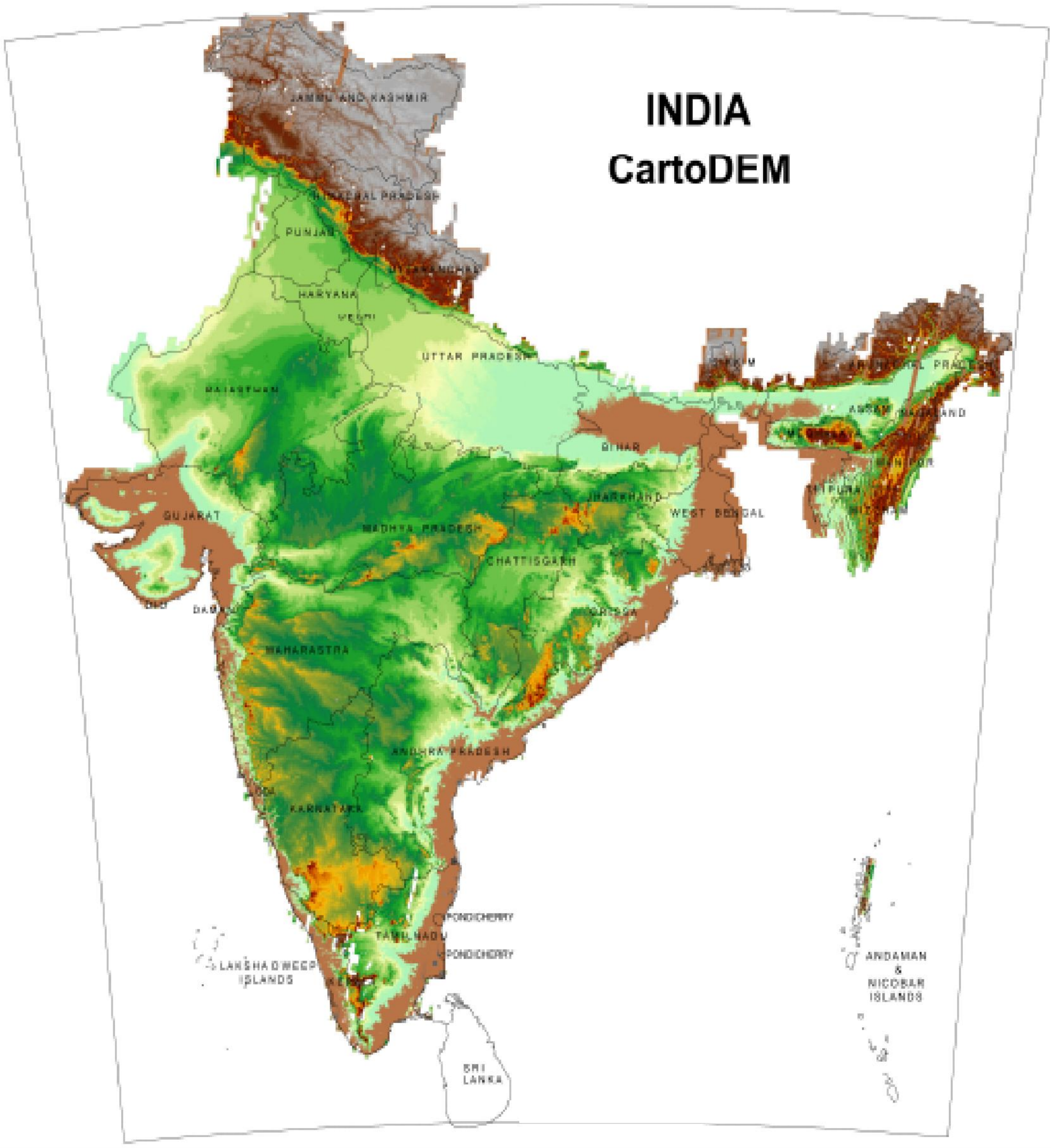
Evaluation of Indian National DEM from Cartosat-1 Data

Summary Report (Ver.1)



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Document Control Sheet

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<tr><td>14.</td><td>Date of Publication</td><td colspan="4">September, 2011</td></tr>
<tr><td>15.</td><td>Abstract (with Keywords)</td><td colspan="4">The objective of this study is to validate CartoDEM data in terms of accuracy and terrain parameter like drainage pattern in comparison with globally available DEMs like SRTM and ASTER. The vertical accuracy achieved is 8m(LE90).

CartoDEM, SST and Cartosat-1</td></tr>
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Contents

Evaluation of Indian National DEM from Cartosat-1 Data

1. Introduction and Background

a. CartoDEM

The Cartosat-1 Digital Elevation Model (CartoDEM) is a National DEM developed by the Indian Space Research Organization (ISRO). It is derived from the Cartosat-1 stereo payload launched in May 2005[1].The Cartosat-1 has a pair of Panchromatic cameras having an along track stereoscopic capability using its near-nadir viewing and forward viewing telescopes to acquire stereo image data with a base-to-height ratio of about 0.63. The spatial resolution is 2.5m in the horizontal plane. Each camera has a pixel array of size 12000 giving a swath of about 27km.

Presently, Cartosat-1 is the only global stereo capable satellite. There are many scientific studies have been carried out using this data for various applications. The Cartosat-1 Scientific Assessment Programme (C-SAP) brought out many interesting results using Cartosat-1 stereo data for various terrain conditions. The users are requested to see the references to get more details about the studies.

This report provides the overall quality of CartoDEM in terms of absolute accuracy and comparison with other globally available DEMs like ASTER[2] and SRTM[3] in terms of accuracy and drainage delineation. The SRTM data was downloaded from USGS EROS centre and ASTER from Earth Remote Sensing Data Analysis Center (ERSDAC).

b. Methodology of DEM generation

The methodology adopted to produce the CartoDEM involved stereo-strip triangulation of 500km strip stereo pairs using high precise ground control points, interactive cloud-masking, automatic dense conjugate pair generation using matching approach [2]. Seamless homogeneous DEM is produced by TIN modeling of irregular DEM, interpolation for regular DEM generation and automatic strip to strip mosaicing. These automatically generated DEM tiles are further evaluated for quality and tile editing to remove anomalies. The detailed design and methodology can be referred [4&5.] The Figure 1 shows the function flow of CartoDEM generation for a segment of 500km.

The primary output unit is a tile of 7.5’ X 7.5’ extents with DEM spacing of 1/3 arc-sec, and co-registered ortho-image of resolution 1/12 arc-sec. However data sets are available at 1 and 3 arc-sec.i.e. 30m and 90m spacing at equator which are generated by sub sampling the original 1/3 arc-sec data. The CartoDEM is a surface model of elevation and covers land surfaces of India. It is comprised of tiles that contain at least 0.01% of Indian landmass are included. As per the design of CartoDEM, the DEM accuracy is 8m at LE90 and 15m at CE90 for ortho data.

2. Validation Approach and Methodologies

a. Absolute accuracy

To study the absolute vertical accuracy of DEM's, three test areas were chosen in such way that it comprises topography of flat (coast), hilly and mixed area. The precise ground control points acquired from dual frequency geodetic survey grade GPS receivers have been used in relative positioning mode. The GCPs have the vertical accuracy of better than 50cm. For one test site i.e. Alwar, aerial DEM with vertical accuracy of 50cm is used as reference. The flow chart of validation is given in Fig.2.

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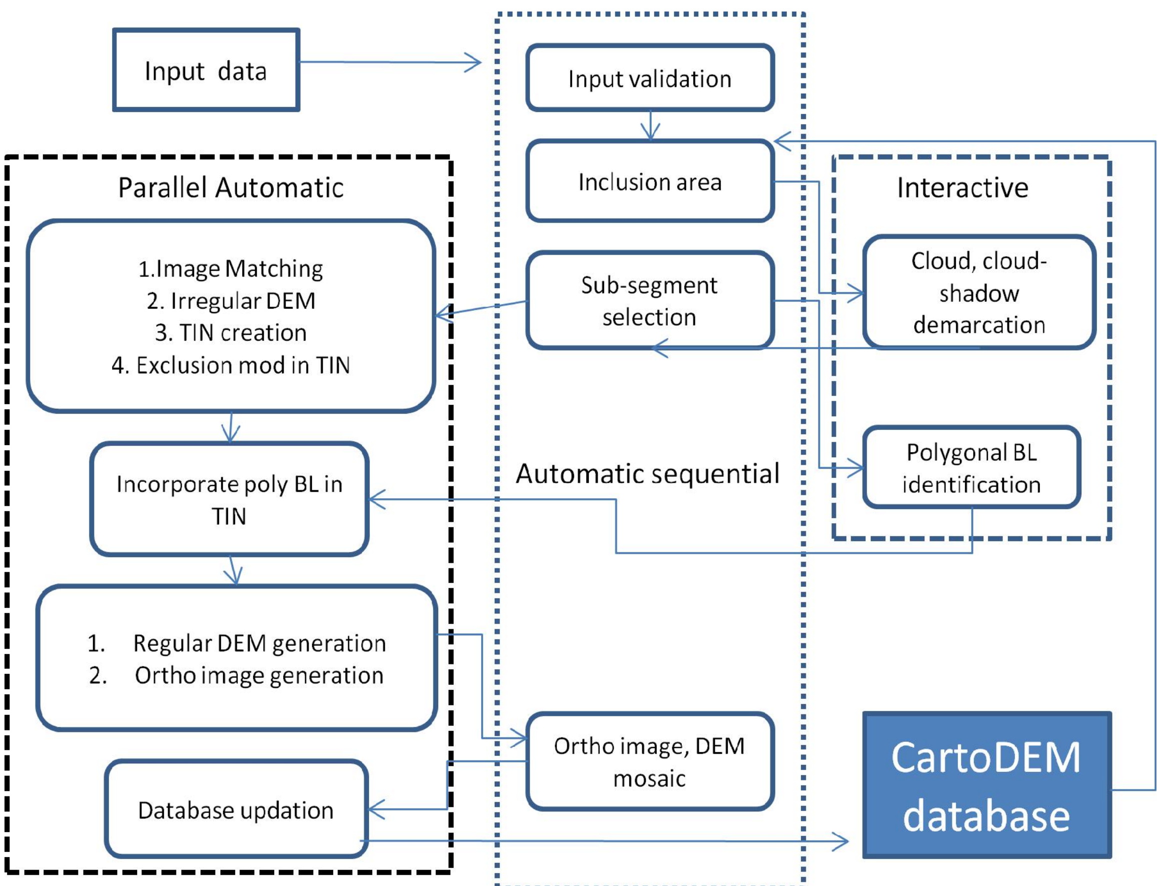


Figure 1: Functional Flow of CARTODEM Generation for a Segment

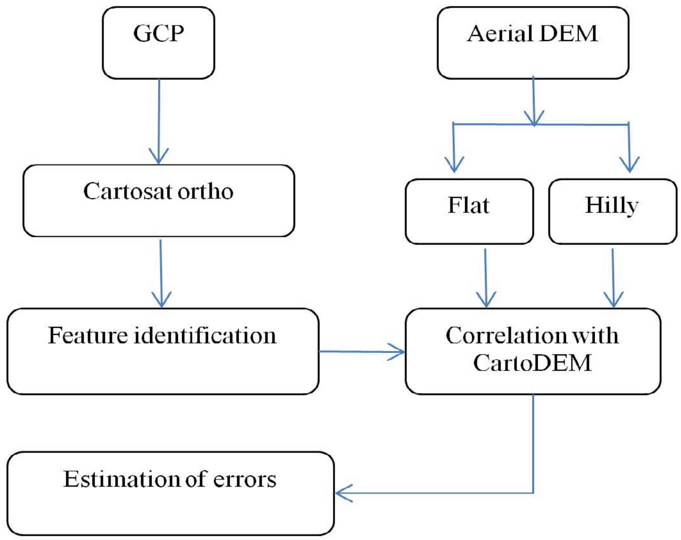


Figure 2: Flow chart of evaluation procedure

Test Area1: Jagathsinghpur, Orissa

The terrain is mostly flat, with the elevation ranges from 0 to 25m above MSL. The DEM at 30m and 90m is validated by comparing it with the elevations of ground control points. A total of 15 points were used for the present study (see Fig.3). The RMSE of CartoDEM30 and CartoDEM90 is 3.4 and 3.44m respectively and Linear Error (LE 90) is 4.7m (see Table-1)

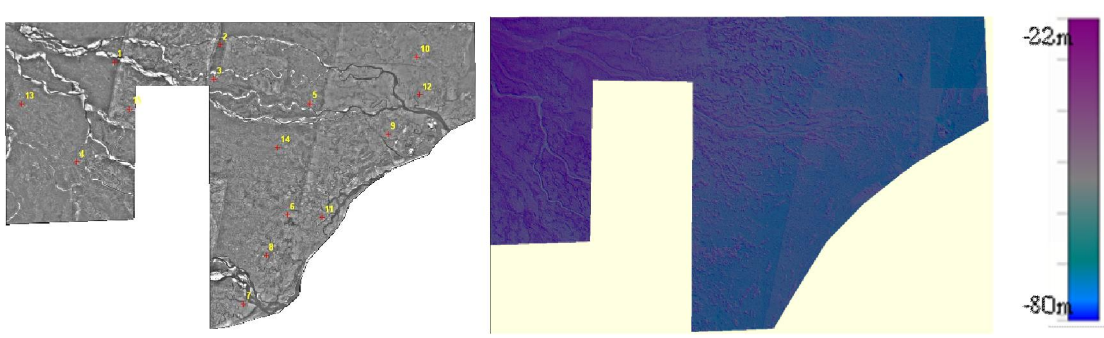


Fig.3. Distribution of control points and CartoDSM- Test Site:Jagatsinghpur

Table 1: Elevation error w.tth respect to GCPs

S.No	Residual (m) on CartoDEM 30 (control point elevation – DEM)	Residual (m) on Carto DEM90 (control point elevation – DEM)
1	-3.69	-3.69
2	-3.63	-2.63
3	-0.29	1.71
4	-0.78	0.22
5	-4.04	-3.04
6	-2.47	-0.47
7	-5.10	-7.10
8	-2.27	-2.27
9	-1.45	-2.45
10	-3.71	-2.71
11	-3.68	-1.68
12	-4.76	-4.76
13	-3.96	-3.96
14	-1.21	-1.21
15	-4.83	-5.83

Test Area2: Dharmsala, Himachalapradesh

The study area is part of Dhamashala, Himachal Pradesh. The elevation in the study area varies from 650m to 4850m above WGS-84 ellipsoid. The DEM at 30 m and 90 m is validated by comparing with elevations of ground control points. A total of 8 points were used in the present study (see Fig.4). The RMSE of CartoDEM30 and CartoDEM90 is 4.72m and 4.79m respectively. The LE 90 of CartoDEM30 and CartoDEM90 is 7m and 8m respectively (see Table 2).

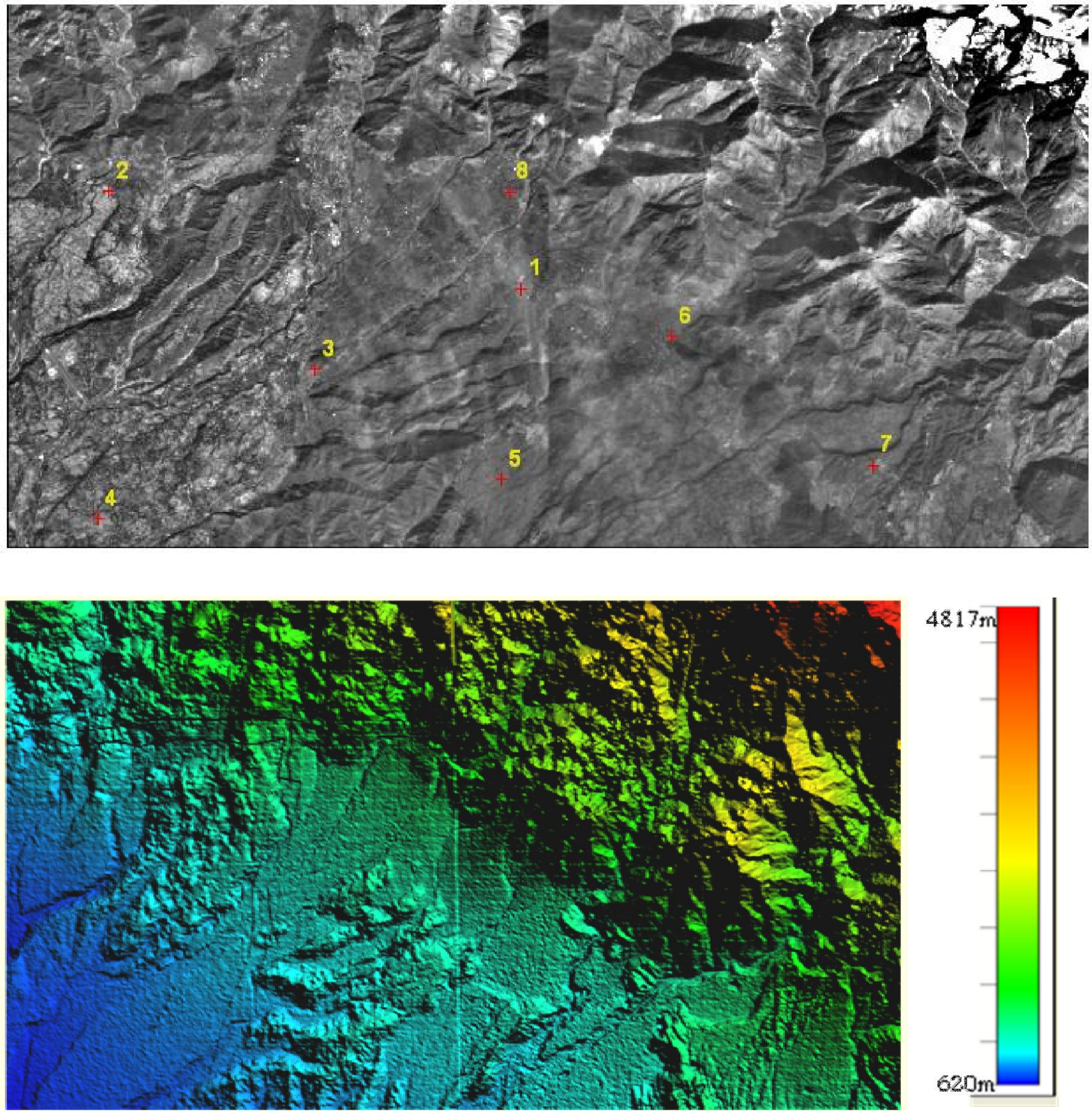


Fig.4. Distribution of Check points and CartoDSM – Test site: Dharamshala

Table 2: Elevation error w.tth respect to GCPs

S.No	Residual (m) on CartoDEM30 (control point elevation – DEM)	Residual (m) on CartoDEM90 (control point elevation – DEM)
1	-6.14	-3.69
2	2.43	-2.63
3	-1.02	1.71
4	2.53	0.22
5	-10.55	-3.04
6	6.12	-0.47
7	3.41	-7.10
8	8.03	-2.27

Test Area3: Alwar, Rajastan

The study area includes part of Alwar district, Rajasthan. It comprises both plain and hilly terrain. The elevation range in the study area varies from 150 m to 650 m above WGS-84 ellipsoid. For comparison purpose, DEM generated from aerial photographs is used as reference whose vertical accuracy is better than 50cm. The aerial DEM was generated at 30 and 90m postings. The DEMs are validated by taking independent checkpoints (ICP) on reference and CartoDEMs (see Fig.5). A total of 59 ICPs are used for validation of CartoDEM30 and CartoDEM90 postings. The RMSE of CartoDEM30 and CartoDEM90 is 4.7m and 5.5m respectively and LE 90 for CartoDEM30 and CartoDEM90 is 7.3 and 8.0 m respectively (see Fig. 6).

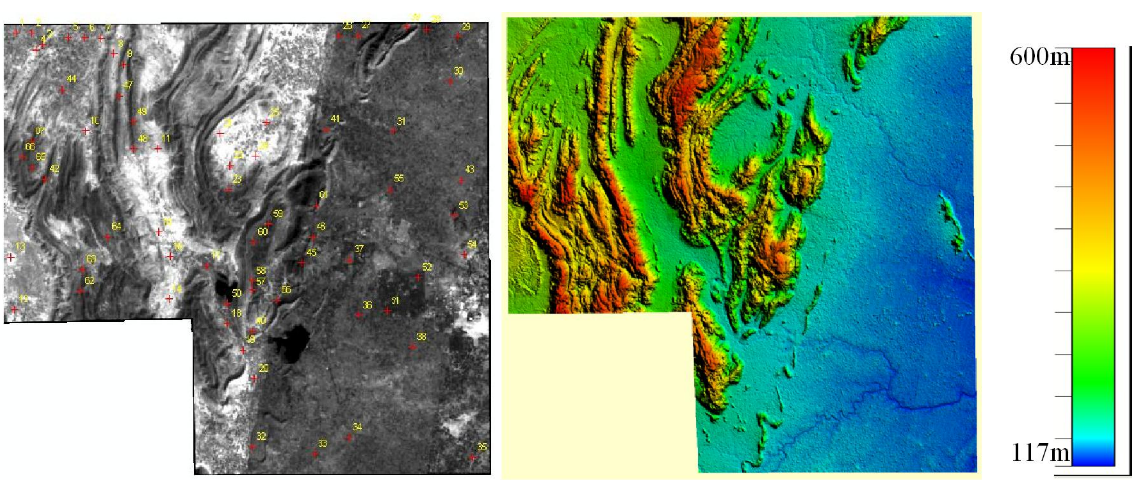


Figure 5: Distribution of Check points and CartoDSM – Test site: Alwar

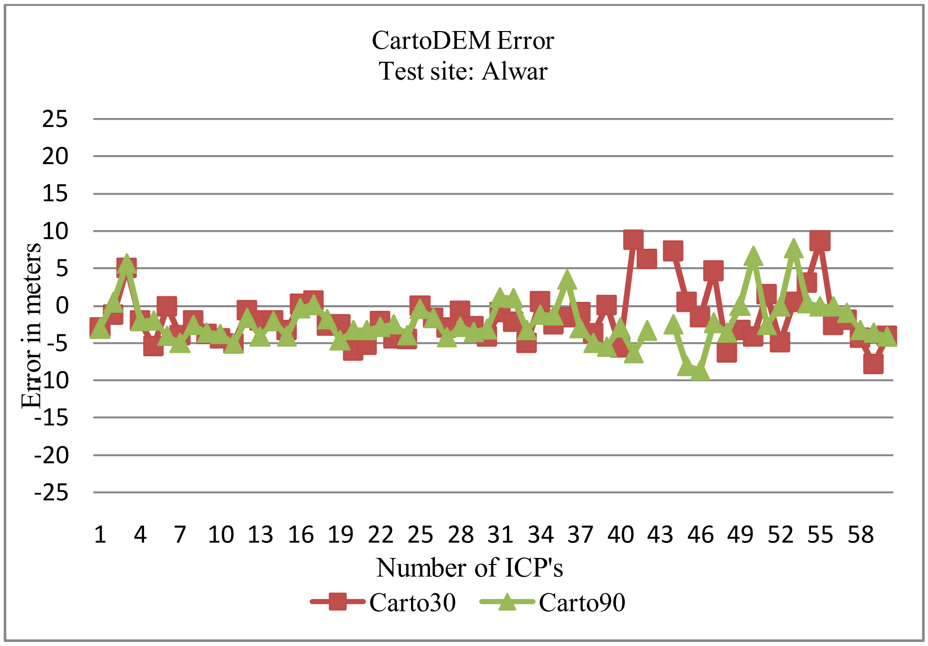


Fig. 6: Difference in accuracy between CartoDEM and Aerial DEM

b. Comparative studies with ASTER and SRTM

A comparative study of CartoDEM with other global DEMs like SRTM and ASTER data has been carried out using in terms of accuracy and drainage pattern analysis for two test data.

Inter comparison of CartoDEM and SRTM - Relative Accuracy

Inter comparison of CartoDEM90 and SRTM 90m were carried out for whole of India and histogram was generated. Overall 400million points were compared and represented as bins of difference in height between the DEMs. It can be observed from the Fig.7, that 90% of data sets were within the stated accuracy of 8m.

For three test sites, difference in elevation is shown in Fig.8, 9 and 10. It is observed from these figures that 90% of elevation difference is within 8m.

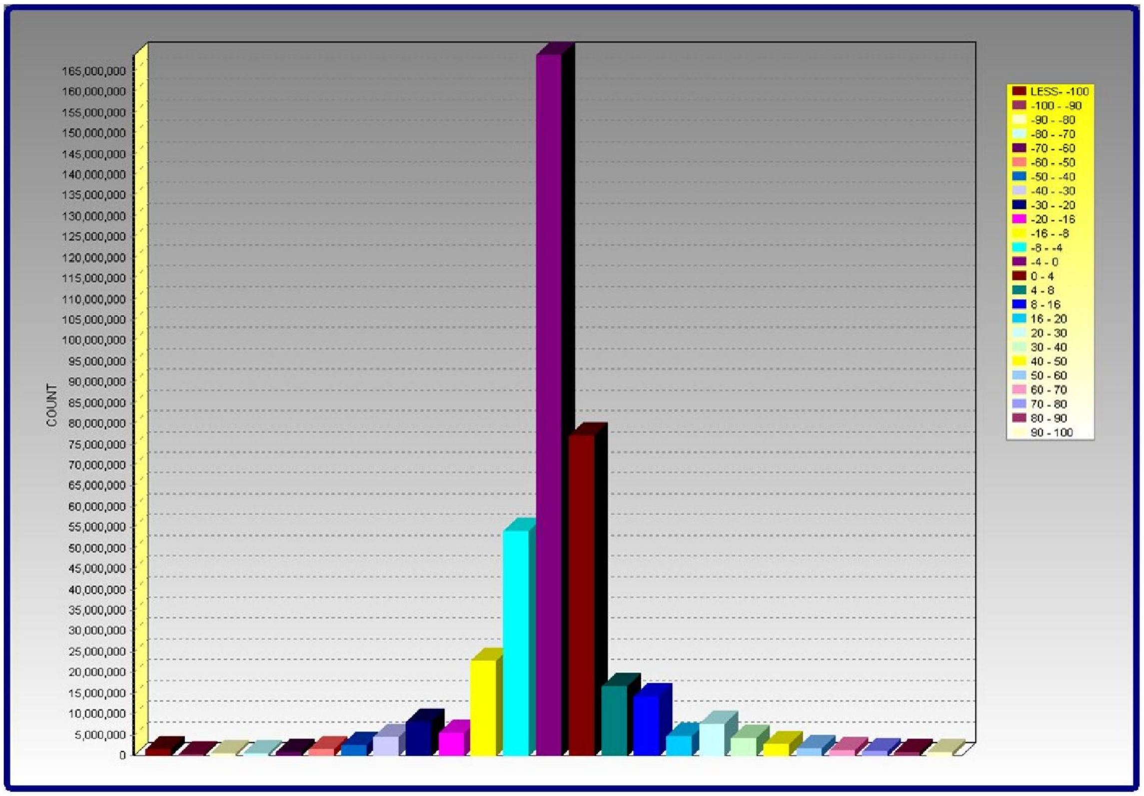


Fig 7: Histogram difference in elevation between CartoDEM and SRTM for Whole of India

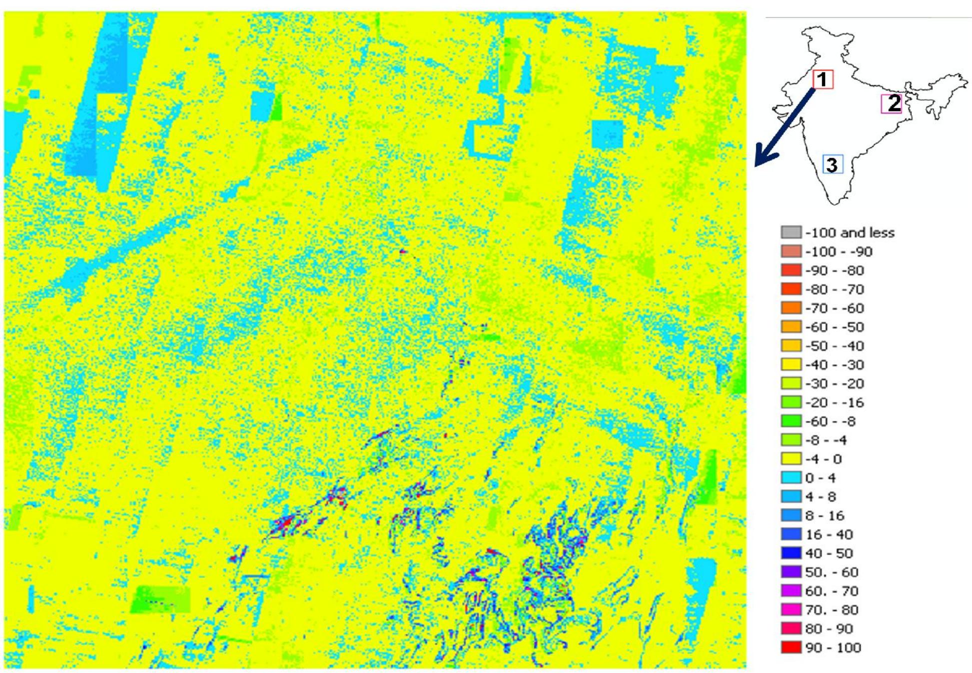


Fig.8: Difference in elevation between CartoDEM and SRTM

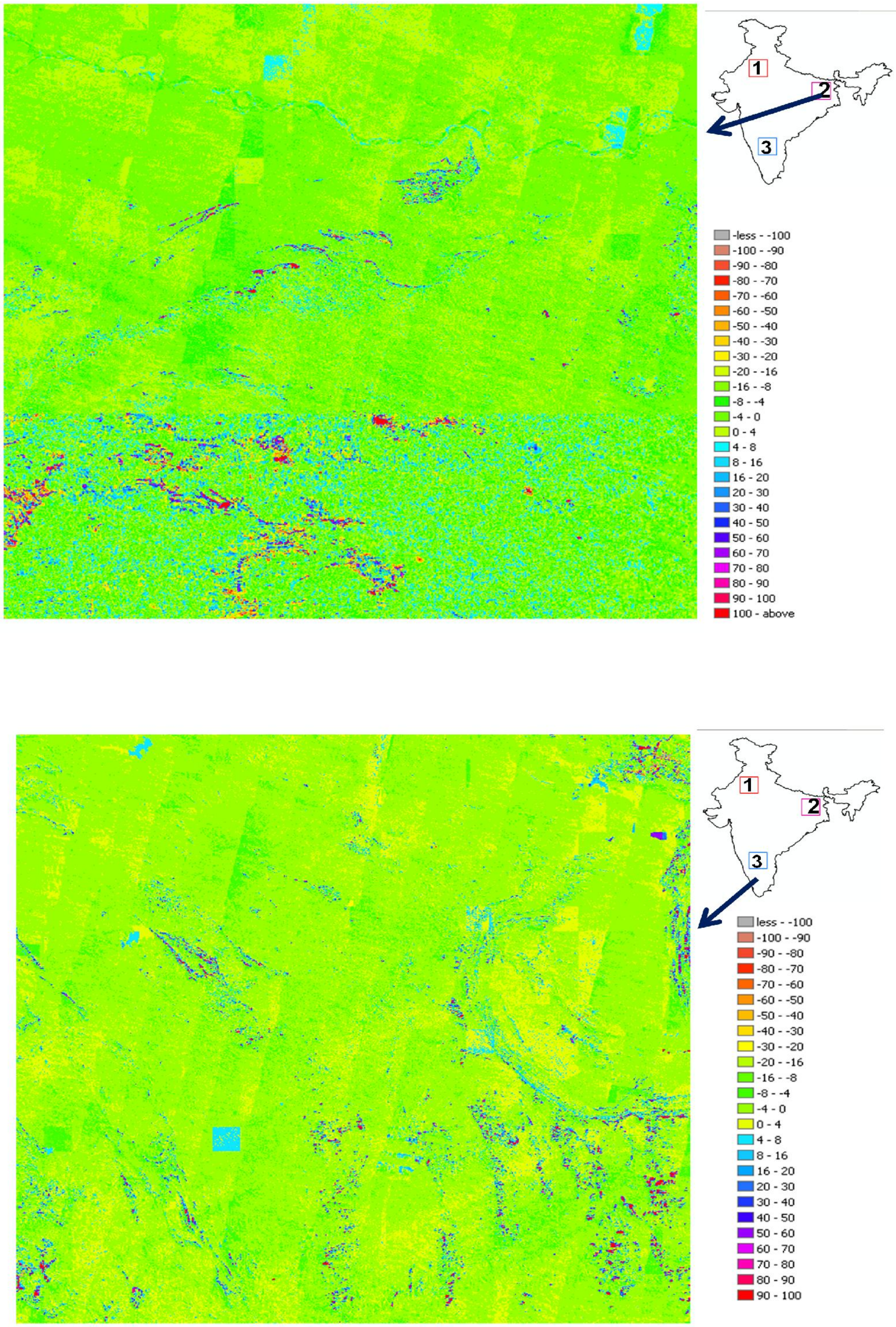


Fig.10: Difference in elevation between CartoDEM and SRTM

Drainage analysis

The two areas were chosen because hilly terrain allows easy understanding of flow depiction.Primary objective of this study is to show the demarcation capability of CartoDEM in comparison with SRTM and ASTER. Drainage delineation analysis has been carried out in comparison with ASTER and SRTM for hilly data since hilly terrain

allows easy understanding of flow direction. Primary objective of this study is to show the demarcation capability of CartoDEM.ArcHydro tool is used to demarcate watershed (both varying catchment and river flow) from the digital elevation data.

By the stream definition factor, it is possible to reduce or increase the density of the streams. By this factor, streams have been classified as primary (minimum) flow, secondary (medium) flow and tertiary (maximum) flow. The results for SRTM (90m), ASTER (30m) and CartoDEM (30m, 90m) are separately derived using MSL (WGS-84 converted to EGM) as a common height reference and compared to understand demarcation results.

CartoDEM Vs ASTER (30m spacing)

From the Fig.11a&11b, it is observed that Cartosat-1 shows a clear demarcation of the catchment ridgeline. Cartosat-1 further shows a good demarcation of secondary flows while ASTER fails to demarcate the secondary flow direction. The smaller catchments obtained from Cartosat-1 are better demarcated and the tertiary flow shows a natural pattern whereas straightening of flow is observed in case of ASTER data with flow densely packed together that did not represent a natural flow. The statistical representation of drainage flow is given in Fig. 12a&12b. It is observed that the delineation of drainage length is more in CartoDEM compared to ASTER where shortening of drainage is present.The similar pattern is observed in primary and secondary flow also.

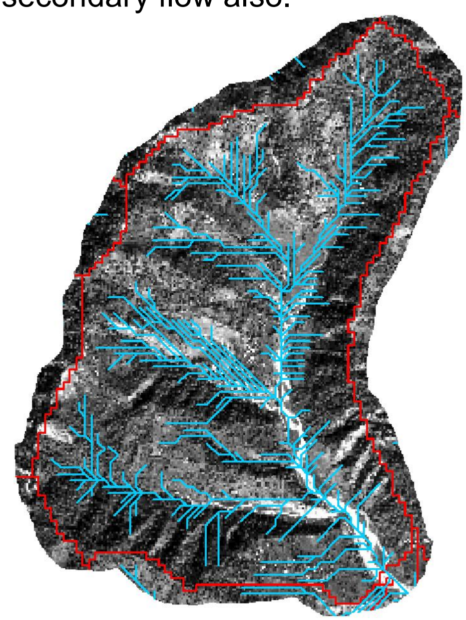


Figure 11a. ASTER 30

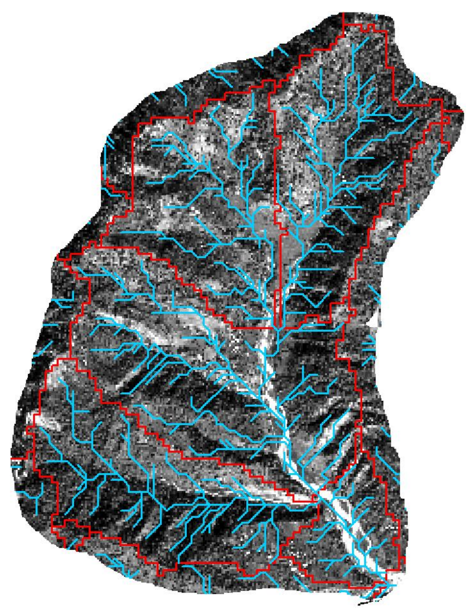


Figure 11b. CartoDEM 30m

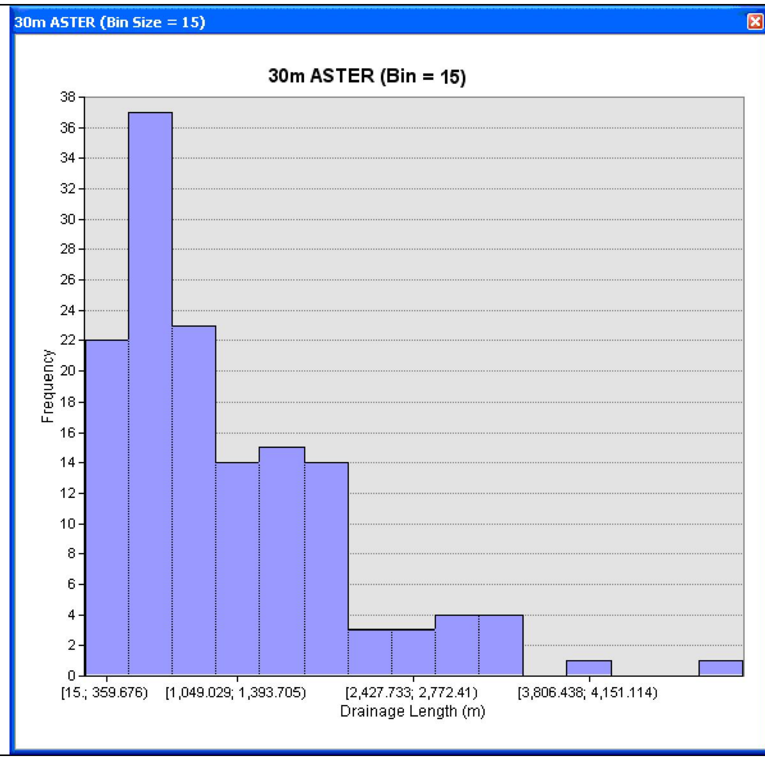
Count: 141	
Minimum: 15	
Maximum: 5185	
Sum: 157066	
Mean: 1114	
SD: 889	

Figure 12a: ASTER30 Drainage – Primary flow (length in meters)

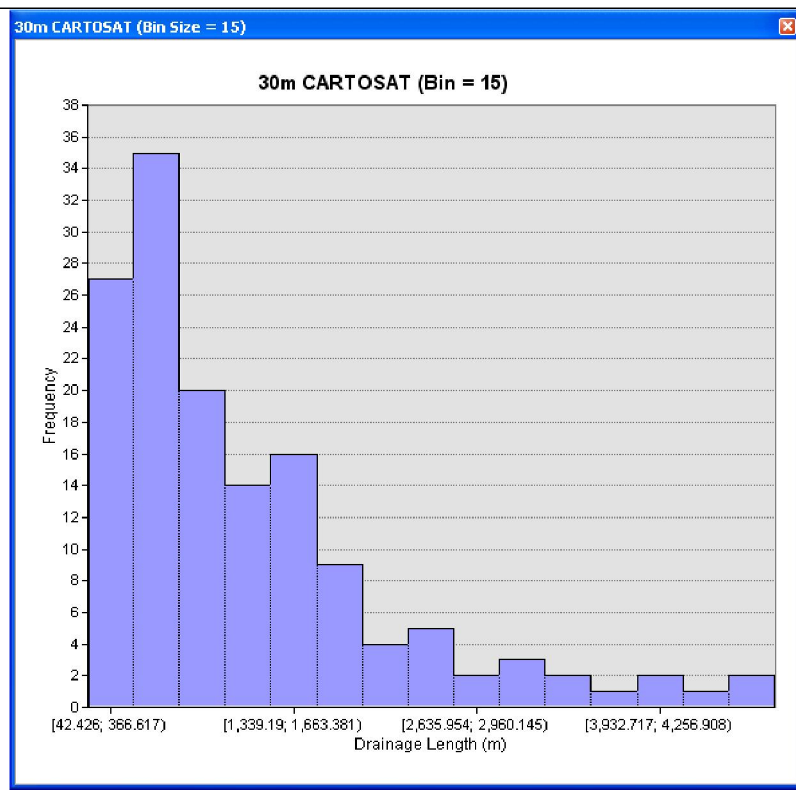
Count: 143	
Minimum: 42	
Maximum: 4905	
Sum: 162969	
Mean: 1139	
SD: 1025	

Figure 12b: CartoDEM30 Drainage – Primary flow (length in meters)

CartoDEM Vs SRTM (90m spacing)

From the Fig.13a&13b, it is observed that both SRTM and CartoDEM 90m spacing is closely matching in terms of catchment delineation and flow depiction. The same result is observed and shown as statistics in Fig. 14a&14b.

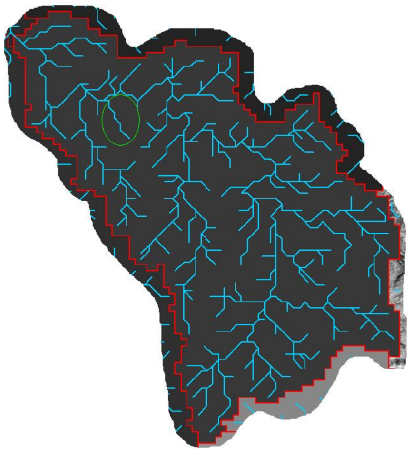


Figure 13a. SRTM90

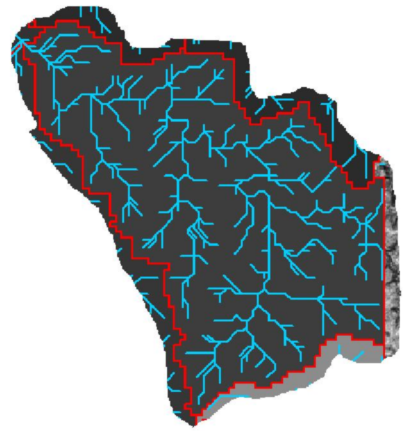


Figure 13b. CartoDEM90

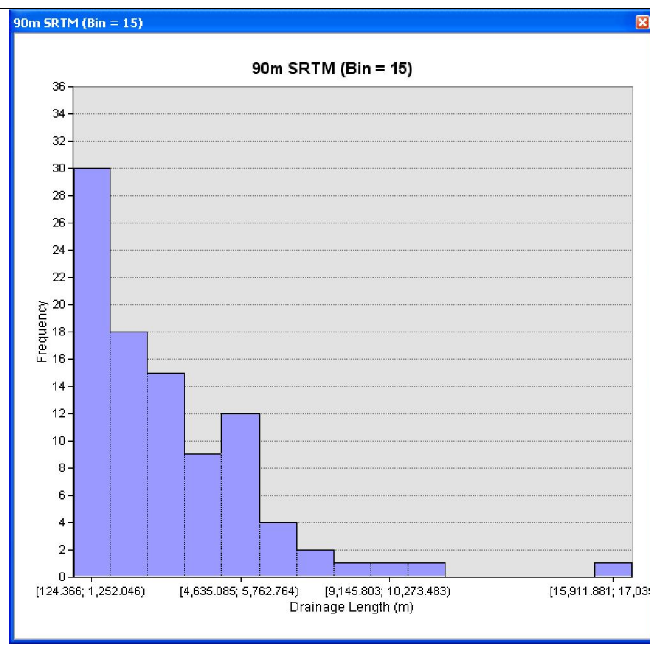
Count: 94	
Minimum: 124	
Maximum: 17040	
Sum: 279803	
Mean: 2977	
SD: 2697	

Figure 14a: SRTM90 Drainage – Primary flow (length in meters)

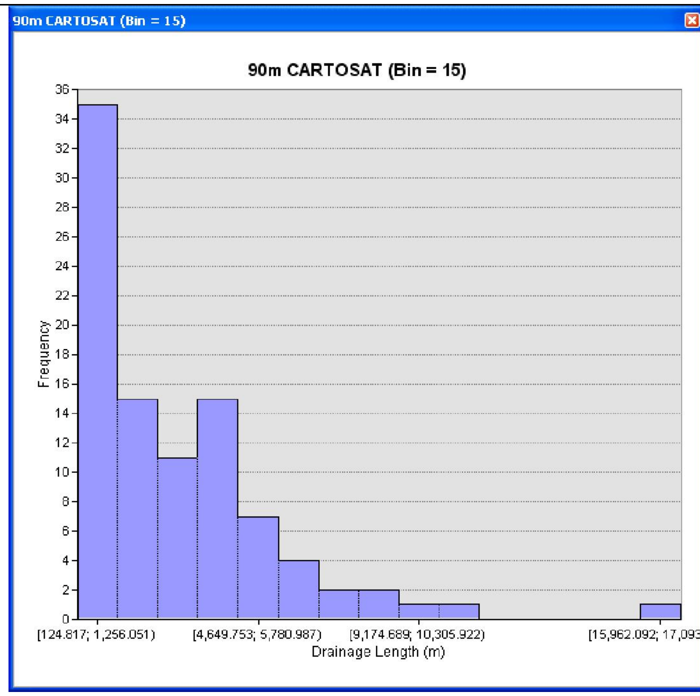
Count: 94	
Minimum: 125	
Maximum: 17093	
Sum: 275478	
Mean: 2931	
SD: 2743	

Figure 14b: CartoDEM90 Drainage – Primary flow (length in meters)

3. Quality issues

The CartoDEM was generated with fully automatic s/w and hence the typical DEM errors that occur in automatic algorithm like match point failure in hill top and large triangles formation in plain area were exist. Apart from this, mosaic errors across tiles due to local vertical error are also observed.

4. Data and meta information format

All the DEMs are available in Geotiff format with geographic latitude and longitude and WGS84 vertical datum. The DEM postings are at 30m and 90m at equator with corresponding co-registered ortho data. Table 3&4 provides details about meta information of DEM and ortho data.

Table 3 :CartoDEM Product Meta Information

Generating Agency	National Remote Sensing Centre
Copyright	NRSC
Contents	Digital images of Raster DEM and Orthorectified satellite imagery
Image Format	Geo-Tiff
Data type DEM	Signed short (2 bytes)
Data type Ortho-image	Unsigned short (2 bytes)
Satellite	Cartosat-1
Sensor	PAN Stereo
Datum	WGS84
Projection	Geographic
Ortho-image Resolution	1/12arc sec ~ 2.5 m
DEM Posting	1/3arc sec ~ 10m 1 arc-sec ~ 30m 3 arc-sec ~90m
DEM Accuracy (Planimetric) –CE90	15 m
DEM Accuracy (Elevation) –LE90	8 m
DEM Ellipsodial Height Units	Meters
DEM Value for undefined	-999
Tile Extents (Size)	7.5'x 7.5' ~ 13.5 km x 13.5 km
Tile Referencing Scheme	South-West Lat-Lon is provided in tile name
DEM Tile Naming Convention	CD_N<SWLAT>_E<SWLON>_DEM.tif
Ortho Image Tile Naming Convention	CD_N<SWLAT>_E<SWLON>_ORTHO.tif
Request Id	
Request Processing Date	
Product Media	CD/DVD/FTP
No of tiles (images) in the User request 24 DEM/ORTHOIMAGE pairs	

Table 4: List of DEM tiles

Tile No Status Segments	**MapsheetId**	**SW-Lat**	**SW-Lon**	**Quality Status(*)**	**M-Multiple S-Single**
1	Not Available	12.375	75.375	7	M

Note: Quality Status(*) and Description

5 – OK, 6 - Mosaic distortions,7 - Other distortions,8 - Mosaic and Other distortions,9 - Reject polygon,10 - Mosaic distortion and Reject polygon,11 - Other distortion and Reject polygon,12 - Mosaic and Other distortion and Reject polygon

5. Related works

The users are requested to visit ISPRS-ISRO Cartosat-1 Scientific Assessment Programme (C-SAP) to know more about Cartosat-1 capability and its application potential.

6. Summary and Conclusions

Statistically, CartoDEM is meeting the specification of vertical accuracy i.e. 8m at 90% confidence. Most of the tiles have substantially better than 5m accuracy at 1σ (67%). The CartoDEM contain anomalies and artifacts that may reduce its usability for certain applications, because they can introduce large elevation errors on local scales. However, for the generation of drainage pattern, 3-D perspective views , viewshed analysis and vertical control points for further processing of various satellite data as well as reference for evaluation of coarser DEM's, this data would be useful. The DEM is complimented with corresponding ortho data and hence this will become a unique data set available for the user community.

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Applications

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